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(54) **Wellbore drilling tool**

(57) There is disclosed a drilling tool 10 of the type having a downhole motor, e.g. turbine 16, 17, and a method of operating the tool in drilling a wellbore. The bit of the tool may be rotated either by actuation of the turbine 16, 17 during normal drilling operations, or by the application of torque to the drill string (not shown) from which the tool 10 is suspended during the performance of certain operations which require that the bit be rotated at low speed and with high torque. A one-way clutch 25 mounted between the tool casing 11 and the shaft 12 allows the turbine 16, 17 to rotate the shaft in one direction (e.g. clockwise) but causes the casing 11 to rotate the shaft 12 when the turbine 16, 17 is inoperative and the drill string and casing 11 are rotated in the same direction.

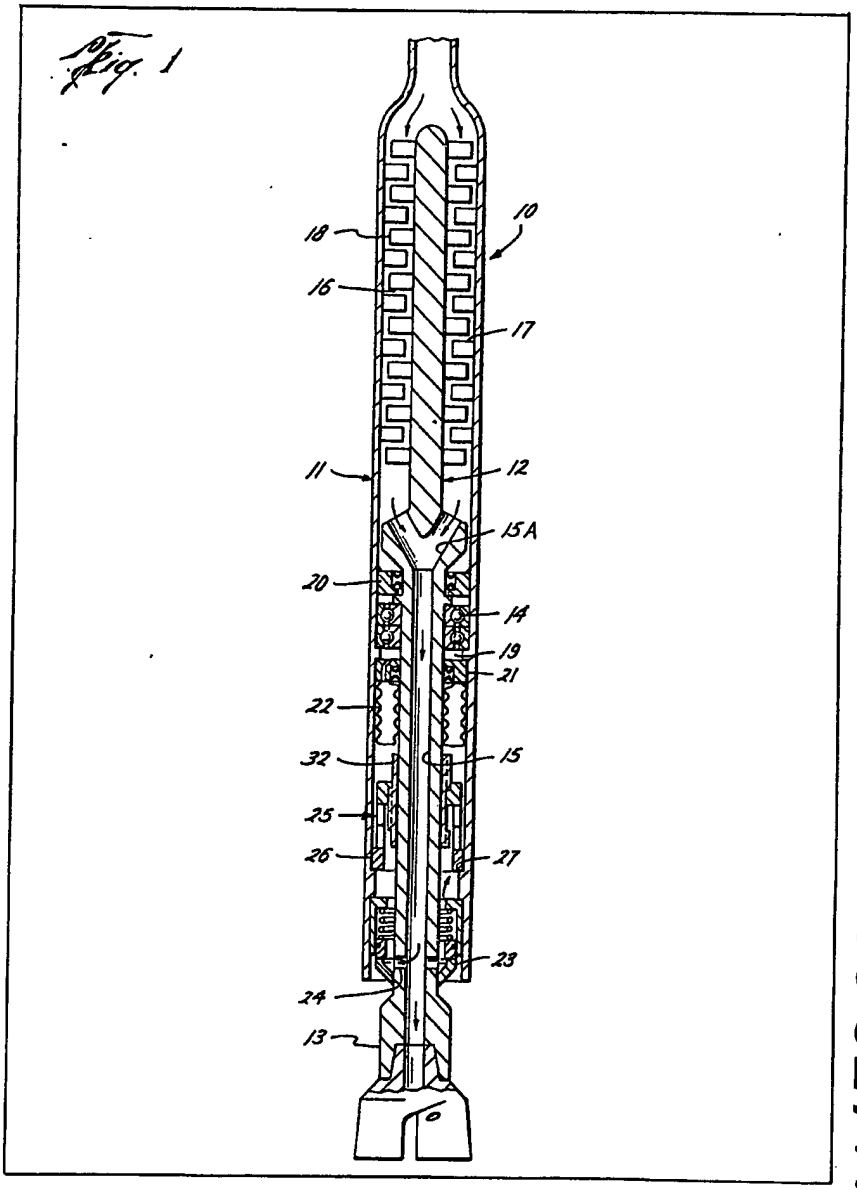

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Fig. 1

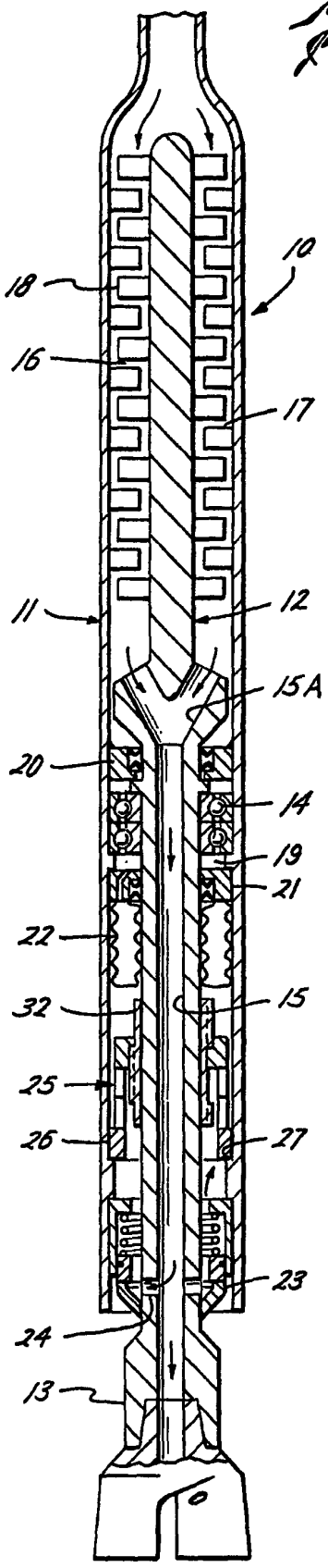


Fig. 4

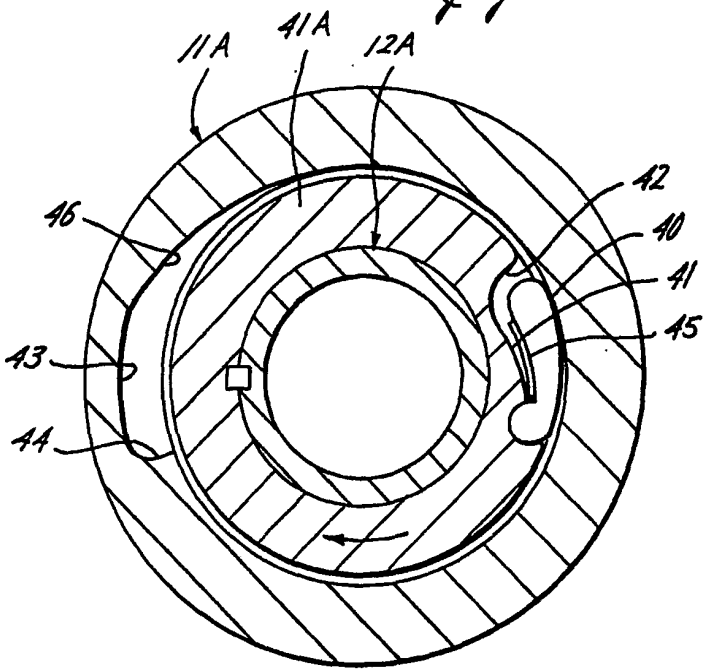
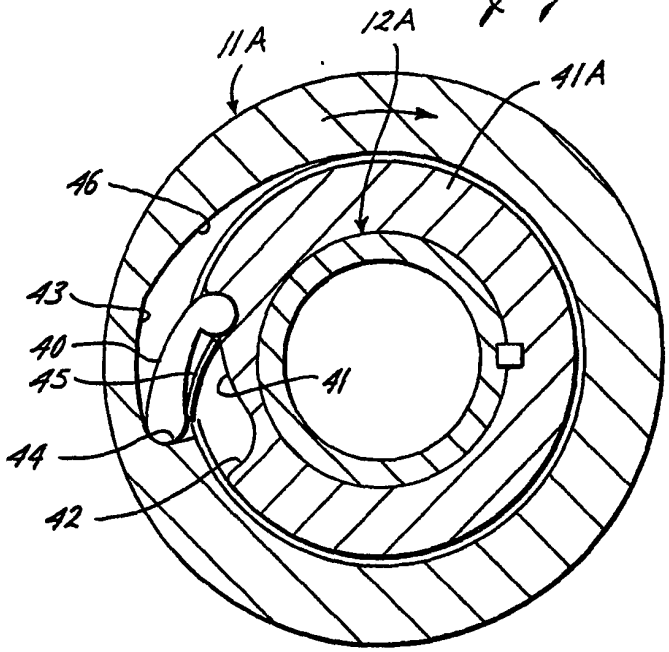


Fig. 5



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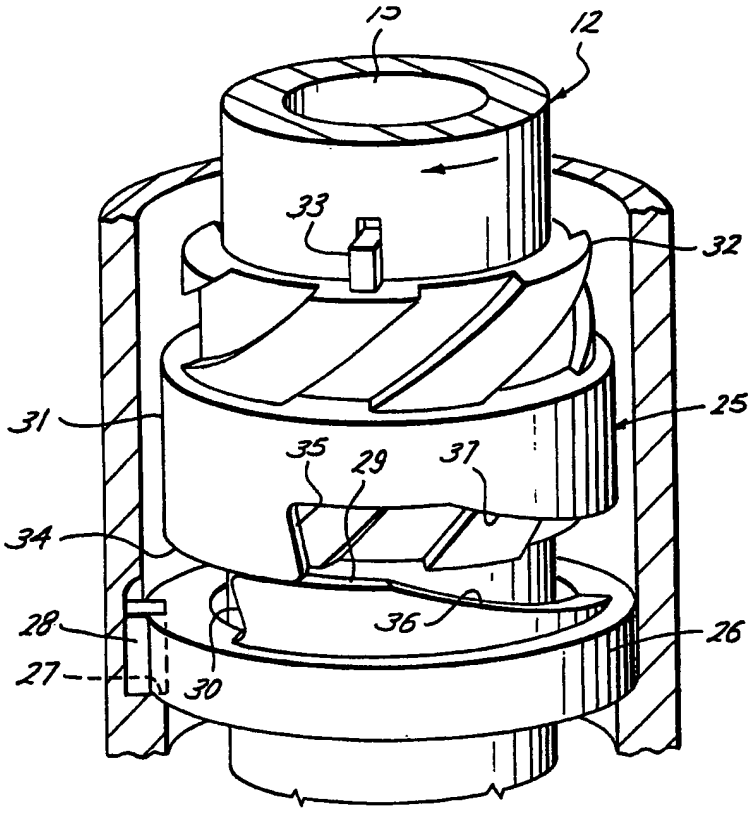

Fig. 2

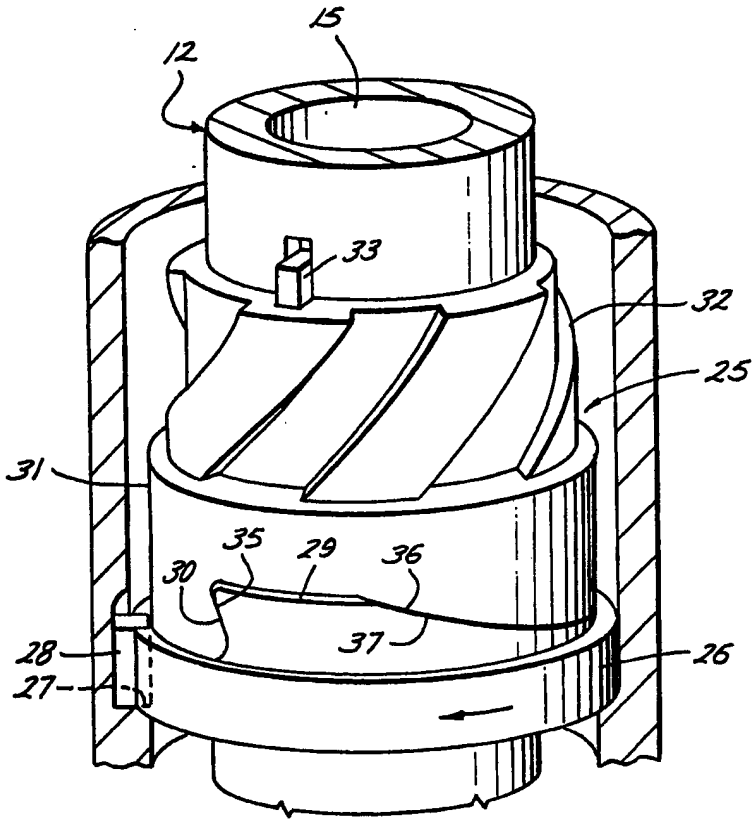

Fig. 3

SPECIFICATION

W llb r drilling tool and method f operating same

This invention relates in general to wellbore drilling tools and methods of operating same. More particularly, it relates to improvements in tools and methods of this type wherein a shaft from which a bit is suspended is supported for rotation within a case suspended from a drill string within a wellbore, and a motor is disposed between the case and shaft for rotating the shaft and thus the bit with respect to the case.

Tools of this type permit the bit to be rotated without having to transmit rotation thereto through the drill string, which may be many thousands of feet in length. However, in the drilling of a wellbore with a tool of this type, there are many instances in which the operator may wish to rotate the bit slower but with greater torque than is possible with downhole motors. For example, this would be useful in releasing a stuck bit, or in reaming out a wellbore as it is first entered by the bit. Also, an operator may wish to rotate the bit slowly to prevent damage to it in the event junk is in the wellbore, or as he begins a milling operation.

Drilling tools such a turbodrills, which are driven in response to the circulation of drilling fluid through them, are especially ill suited to performing these additional operations because the shaft is indirectly connected to the case. Consequently, they are incapable of giving an accurate indication of the rotational speed of the bit, and thus often fail to provide the operator with the control he needs to satisfactorily perform such operations.

An object of this invention is to provide a drilling tool of this type which may be selectively operated to rotate the bit at slow speeds and with high torque.

Another object is to provide such a tool which may be so operated solely through manipulation of the drill string at the surface, and, more particularly, automatically in response to the application of torque to the string and thus to the case of the tool.

A further object is to provide such a tool and method which do not require skilled operators, and wherein the tool is simple and inexpensive to construct.

A still further object is to provide such a tool which can be constructed through a relatively simple and inexpensive modification of an existing tool of this type.

These and other objects are accomplished, in accordanc with th illustrated embodiments of the present invention, by a tool of the type described having clutch means engageable to rotate the case with the shaft, when the case is rotated with respect to the said shaft in the one directional sense in which the motor rotates the shaft, and disengageable to permit the shaft to be rotated in said one directional sense with respect to the shaft in response t actuation of the motor. Consequently, in the drilling f a wellbore, the operator f the t ol may, if h wish s t apply greater torque t the bit f r any reason, including one or more of those above-described, selectively apply torque to the drill string at the surface in order to rotate the case in such one directional sense with respect to the shaft. Alternatively, during normal drilling operations, he may selectively actuate the motor to rotate the shaft in said one directional sense with respect to the case.

The motor is of such construction as to rotate the shaft in the same direction in which the drill pipe sections are rotated when being made up, so that the reaction from the torque applied to the shaft in rotating it will not unthread the drill pipe sections. Thus, when the threaded connections between the drill pipe sections are of right hand, as is customary, the shaft will be rotated clockwise as viewed in a direction downwardly along the axis of the tool. For the same reason, when the bit is to be rotated through the case, the drill string, and thus the case, are rotated in the same directional sense — i.e., normally clockwise.

As will be appreciated, as long as the shaft continues to be rotated by the motor at a speed greater than the case is being rotated through the drill string, the bit will continue to be driven by the motor. The clutch means is engaged to selectively drive the bit through the drill string when the bit is stuck, or otherwise slowed down to such an extent that it is rotating at a slower speed than the case is rotated through the drill string. If the bit is rotating at a relatively high speed, it may be necessary to stop or at least slow down the motor in order to engage the clutch means.

Then, in the event the bit is unstuck, or otherwise free to rotate faster, the clutch means is automatically disengaged when the shaft is rotated by the motor at a speed greater than that at which the case is rotated. If the motor has been stopped or slowed down, and the operator desires to resume normal drilling operations, he need only increase pressure of the drilling fluid to cause the motor to rotate the shaft at the desired speed. In either case, torque applied to the case through the drill string may be released until a further need arises to rotate the bit with the case.

As illustrated, the motor of the tool comprises a means for rotating the shaft in response to circulation of drilling fluid through the tool. More particularly, the rotating means comprises turbine blades on the shaft and case, which make up a turbine section of a tool of this type known in the art as a turbodrill. As previously indicated, this invention is particularly well suited for tools of this latter type inasmuch as it provides a means for indicating the amount of torqu being applied to the bit when the clutch means is engaged to rotate the bit with the cas . In the case of a turbodrill, it is possible for the operator to rotate the bit with the case without discontinuing circulation of the drilling fluid, b cause the turbine section is incapable of imparting rotation to the shaft and thus th bit without fairly substantial

pump pressure applied to the drilling fluid.

The clutch means includes a clutch part carried by either the case or the shaft for movement with respect thereto into a position in which it is engaged with a clutch part on the other of the case or shaft, whereby the shaft may be rotated with the case when the case is rotated with respect to the shaft in the one directional sense. More particularly, the first-mentioned clutch part is movable with respect to the case or shaft on which it is carried into another position in which it is disengaged from the other clutch part so as to permit the shaft to be rotated with respect to the case in such one directional sense in response to actuation of the motor. As shown in the illustrated embodiments of the invention, the clutch part may be movable either in an axial direction or a radial direction with respect to the case or shaft on which it is carried.

In one illustrated embodiment of the invention, the clutch means comprises a lug on one of the case or shaft and having a shoulder facing in the one directional sense, a ring carried by the other of the case and shaft and having a splined connection for vertical movement with respect to it, and a lug on the ring having a shoulder engageable with the shoulder on the first-mentioned lug, when the case is rotated with respect to the shaft in said one directional sense, so that the shaft will rotate with the case as the case continues to be so rotated. More particularly, the ring and the first-mentioned lug have cam surfaces which move the ring vertically with respect to the case or shaft on which it is carried, so that the lug on the ring is free to move past the other lug to permit the shaft to be rotated with respect to the case in said one directional sense in response to actuation of the motor. In the illustrated embodiment of the invention, the first-mentioned lug is on the inside of the case, and the ring and the lug thereon are carried on the outside of the shaft. More particularly, the spline is preferably helical and extends in such one directional sense from its upper to its lower end.

In another illustrated embodiment of the invention, the clutch means comprises a recess formed in one of the case and shaft, and a dog mounted on the other of the case and shaft for movement with respect to it toward and away from the recess. The dog is urged toward the recess, and one end of the recess has a shoulder facing in the one directional sense for engaging a shoulder on the dog, when the case is rotated with respect to the shaft in such one directional sense, so as to rotate the shaft with the case. More particularly, the recess and dog have cam surfaces thereon which force the dog away from the recess to permit the shaft to be rotated with respect to the case in said one directional sense in response to actuation of the motor. As illustrated, the recess is formed on the inside of the case, and the dog is mounted on the outside of the shaft. Preferably, the dog is pivotally mounted on the shaft for swinging toward and away from the recess about a longitudinal axis, and spring means is provided for urging the dog toward the recess.

In the drawings, wherein like reference characters are used throughout to designate like parts:

FIG. 1 is a longitudinal sectional view of a turbodrill having clutch means constructed in accordance with the first-described embodiment of the present invention;

FIGS. 2 and 3 are enlarged, perspective views of a portion of the turbodrill of FIG. 1, with the case thereof broken away to show details of the clutch means, FIG. 2 showing the clutch means disengaged during rotation of the shaft by means of the motor of the turbodrill, and FIG. 3 showing the clutch means disengaged during rotation of the shaft by means of the case; and

FIGS. 4 and 5 are cross-sectional views of a clutch means constructed in accordance with the second-mentioned embodiment of the invention, and forming part of a turbodrill of the type shown in FIG. 1, FIG. 4 showing the clutch means disengaged as the shaft is being rotated by the motor of the turbodrill, and FIG. 5 showing it engaged as the case is rotated in order to rotate the shaft therewith.

With reference now to the details of the above-described drawings, the turbodrill shown in FIG. 1, and indicated in its entirety by reference character 10, includes a case 11 having an upper end which may be connected to the lower end of the drill string (not shown), and a shaft 12 rotatably supported within the case by means of ball bearings 14 carried by the case intermediate its upper and lower ends, and having a bit 13 connected to its lower end beneath the lower end of the case.

The lower end of the shaft has a bore 15 therethrough which connects with the bore through bit 13 at its lower end, and the upper end of the shaft bore 15 is connected by means of openings 15A with the upper end of an annular space 16 between the upper end of the shaft. The turbodrill may be raised and lowered within the wellbore by means of the drill string, and, during drilling operations with the bit 13 in the wellbore, drilling fluid may be circulated downwardly through the string and the turbodrill out the lower end of the bit, and then upwardly within the annulus between the turbodrill and drill string and the wellbore.

Rotation is imparted to the shaft, and thus to the bit, during normal drilling operations, by means of a turbine section within the upper end of the annular space 16 comprising stators 17 carried on the inside of the case and rotors 18 carried on the outside of the shaft. As well known in the art, the rotors and stators are so arranged as to rotate the shaft, in response to the circulation of drilling fluid downwardly through the annular space 16, in a right hand direction — i.e., in clockwise direction as viewed downwardly along the axis of the tool.

As also shown in FIG. 1, the bearings 14, which serve as radial as well as thrust bearings, are contained within a lubricant chamber 19

intermediat upper and lower seals 20 and 21 sealing between the case and shaft with a lower portion of annular space 16. A b lows 22 is connected to the lubricant chamber and arranged within the annular space beneath seal 21 to compensate for changes in pressure outside of the chamber.

The lower end of annular space 16 is sealed off by means of a face-type seal 23, and a port 24 in the shaft connects the bore 15 therethrough with the annular space intermediate the seal 23 and the bearing assembly. Thus, as more fully described in Patent No. 3,971,450, the pressure of the drilling fluid within the turbodrill is substantially equalized across the bearing chamber 19 defined between seals 20 and 21, while the pressure drop of the drilling fluid between the inside and the outside of the tool is carried by the seal 23. The reasons for and advantages of such an arrangement are more fully set forth in the aforementioned patent, and form no part of the present invention, other than to illustrate a preferred form of turbodrill.

The embodiment of the clutch means best shown in FIGS. 2 and 3, and indicated in its entirety by reference character 25, includes a lower ring 26 which is supported on an annular shoulder 27 within case 11 and fixed against rotation with respect thereto by means of a key 28 received within aligned slots in the case and ring. A lug 29 is located on the upper end of the ring and has a shoulder 30 which faces in the same directional sense that the shaft is rotated by means of the motor.

Clutch means 25 also includes an upper ring 31 which surrounds the shaft 12 above lower ring 26 and has a splined connection with a sleeve 32 which fits about and is fixed against rotation with respect to the shaft by means of a key 33 fitting within aligned slots in the shaft and sleeve. The sleeve is supported by the shaft by any suitable means (not shown) so as to permit its movement vertically with respect thereto. Also, of course, it may be formed integrally with the shaft. A lug 34 formed on the lower end of upper ring 31 has a shoulder 35 which faces in a direction opposite to that of shoulder 30 — i.e., in a counterclockwise direction as viewed vertically along the axis of the tool.

Cam means 36 is formed on the upper end of lower ring 26, and cam means 37 is formed on the lower end of ring 31. During normal operation of the tool, when the shaft 12 is being rotated by the turbine motor in a clockwise direction with respect to the case, as indicated by the arrow in FIG. 2, cam means 37 on the ring 31 will slide up and over cam means 36 on lower ring 26, so that lug 34 on the ring 31 will move past lug 29 as the ring 31 moves vertically along its splined connection to sleeve 32.

As shown, the splines are helical in shape and extend in the one directional sense — i.e., in a clockwise direction as viewed vertically along the axis of the tool — from their upper to their lower ends. The inclined surfaces of the spline thus assist ring 31 in moving upwardly as the shaft r tates in a clockwise direction with r spect to the case. Conversely, the inclined surfaces tend to hold ring 31 in its lower position when the case is rotated with respect to the shaft.

As previously discussed, if the bit is stuck or slowed down due to an obstruction, in the well bore, the clutch means may be selectively engaged to rotate the shaft and thus the bit with the case even though the turbine motor is operating at maximum horsepower. In this event, the torque applied to the bit through the drill string will be added to that applied thereto through the motor. Then, when this added torque frees the bit, its rotation with respect to the case will automatically disengage the clutch means so that it will continue to be rotated by the motor, thereby enabling the operator to remove torque applied to the case through the drill string in order to resume normal drilling operations. If, however, the bit is rotating at a relatively high speed when the operator desires to rotate it with the case, rather than with respect to the case through operating of the turbine motor, the circulation of drilling fluid is either discontinued or preferably slowed to such an extent that the shaft rotates clockwise, if at all, at a very slow speed.

In either event, upon rotation of the drill string and thus the case in a clockwise direction, as indicated by the arrow in FIG. 3, lug 29 will rotate in a clockwise direction relatively to lug 34 so as to bring shoulder 30 into engagement with shoulder 35. Then, of course, when the bit is freed, or the tool is selectively operated to permit the shaft to be rotated by the motor by discontinuing rotation of the case and resuming normal circulation of the drilling fluid, lug 34 moves over lug 29 as ring 31 rotates in a clockwise direction.

In the embodiment of the clutch means shown in FIGS. 4 and 5, a dog 40 disposed with a recess 41 in a collar 41A about the outer diameter of turbodrill shaft 12A is pivotally connected thereto for swinging toward and away from the shaft. More particularly, the recess permits the dog to swing inwardly to a position in which the shaft is free to be rotated by the turbodrill motor in a clockwise direction, as indicated by the arrow in FIG. 4. When the dog is so rotated, a shoulder on its outer end faces in the direction opposite to the direction of rotation — i.e., in a counterclockwise direction. A recess 43 is formed in the inner diameter of the case 11A of the turbodrill, and has a shoulder 44 on one end which faces in a clockwise direction — i.e., in the same direction in which the shaft is rotated by the turbine of the turbodrill.

The dog is urged outwardly from its position of FIG. 4 by means of a leaf spring 45 disposed between its inn r side and the recess 41. Thus, as the shaft and thus the dog are rotat d in a clockwise direction, as indicated in FIG. 4, the dog will move away from the shaft into the recess 43 as it reaches a position opposite thereto. However, this does not interfere with rotati n f the shaft freely with respect to the cas , because the end of

recess 43 opposite shoulder 44 has a cam surface 46 which gradually urges the dog 40 from its expanded position back to its retracted position as it moves past the recess 43.

However, when the bit is stuck or slowed down, or the circulation of drilling fluid is either discontinued or slowed down sufficiently to permit the case 11A to be rotated in a clockwise direction at a greater speed than the shaft is being rotated in the same direction, and recess 43 moves into a position opposite the dog 40, shoulder 44 on one end of the recess will engage the shoulder on the outer free end of the dog 40 to cause the dog and consequently the shaft to rotate with the case.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus and method.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

CLAIMS

1. A downhole drilling tool, comprising a pair of concentrically arranged tubular members including a case connectible to a drill string for suspension within a wellbore, and a shaft rotatably supported within the case and connectible to a bit beneath the lower end of the case, and a motor for rotating the shaft and thus the bit in one directional sense with respect to the case, clutch means engageable to rotate the case with the shaft, when the case is rotated with respect to said shaft in said one directional direction, and disengageable to permit the shaft to be rotated with respect to said case in said one directional sense in response to actuation of the motor.

2. Apparatus according to claim 1, wherein said motor comprises means for rotating the shaft in response to circulation of drilling fluid through the tool.

3. Apparatus according to claim 2, wherein the shaft rotating means comprises turbine blades on the shaft and case.

4. Apparatus according to any one of claims 1 to 3, wherein the clutch means includes a first clutch part carried by a first tubular member for movement with respect thereto into a position in which it is engaged with a second clutch part on the second tubular member so as to rotate shaft with the case, when the case is rotated with respect to said shaft in said one directional sense, said first clutch part being movable with respect to the first tubular member into another position in which it is disengaged with the second clutch part so as to permit the shaft to be rotated with respect to the case in said one directional sense in response to actuation of the motor.

5. Apparatus according to claim 4, wherein the first clutch part is carried by the shaft, and the second clutch part is carried by the case.

6. Apparatus according to claim 5, wherein a lug on the case has a shoulder facing in said one directional sense, a ring is carried by the shaft and has a splined connection therewith for vertical movement with respect thereto, and a lug on the ring has a shoulder engageable with the shoulder on the lug on the case, when the case is rotated with respect to the shaft in said one directional sense, so that the shaft will rotate with the case as the case continues to be so rotated, said ring and lug on the case having cam surfaces which move the ring vertically with respect to the shaft so that the lug on the shaft is free to move past the other lug to permit the shaft to be rotated by the motor when the shaft is rotated with respect to the case in said one directional sense.

7. Apparatus according to claim 6, wherein the ring is above the lug on the case.

8. Apparatus according to claim 7, wherein the spline is helical and extends in said one directional sense from its upper to its lower end.

9. Apparatus according to claim 4, wherein a recess is formed in the case, and a dog is mounted on the shaft for movement with respect thereto toward and away from the recess, said dog being urged toward the recess and one end of the recess having a shoulder facing in said one directional sense for engaging a shoulder on the dog, when the case is rotated with respect to the shaft in said one directional sense, so as to rotate the shaft with the case, and the recess and dog have cam surfaces thereon which force the dog out of the recess to permit the shaft to be rotated with respect to the case in said one directional sense in response to actuation of the motor.

10. Apparatus according to claim 9, wherein the dog is pivotally mounted on the shaft about a longitudinal axis.

11. Apparatus according to claim 10, including spring means urging the dog toward the recess.

12. In a method of drilling a borehole with a tool having a bit suspended from a shaft rotatably mounted within a case suspended from a drill string extending to the surface, and a motor disposed between the case and shaft and adapted to be actuated to rotate the shaft in one directional sense with respect to the case, the steps of selectively

(1) applying torque to the drill string at the surface in order to rotate the case in said one directional sense with respect to the shaft and thereby engage clutch means between the case and the shaft which permits the shaft and thus the bit to be rotated in said one directional sense upon continued application of torque to the drill string, or

(2) actuating the motor to rotate th shaft in said one directional sense with respect to the case in order to disengage said clutch means s that the shaft and thus the bit may continu to be rotated in said one dir ctional sense upon c ntinued actuation of the motor.

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